FEC

2-F-37

INSTRUCTION MANUAL

REGATRON

POWER SUPPLY

MODEL 213A

SERIAL No. _____

ELECTRONIC MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

TELEPHONE: (201) LIberty 2-0300 TWX: (201) 542-2273 CABLE: ELMEASCO

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REGATRON®
PROGRAMMABLE
POWER SUPPLY

MODEL 213A

SERIAL No. _____

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

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REGATRON MODELS 213A and 214A

TABLE OF SPECIFICATIONS

OUTPUT
Model 213A—0 to 50 volts, 0 to 1 ampere
Model 214A—0 to 100 volts, 0 to 1 ampere

REGULATION
Line—0.1% or 0.05 volts, whichever is greater, for line change from 105 to 125 volts ac, 50-60 cps.
Load—0.1% or 0.05 volts, whichever is greater, no load to full load.

REGULATION WITH CHOPPER STABILIZATION
(Models 213AK and 214AK)
Line or load—0.01% or 0.003 volt, whichever is greater.

STABILITY—Within 0.1% or 50 millivolts, whichever is greater, for 8-hours after 30-minutes warmup, under fixed line, load, and temperature conditions, with precision high stability external programming resistor.

STABILITY WITH CHOPPER STABILIZATION—0.05% + 2 millivolts, same conditions as above.

RIPPLE—1 millivolt RMS maximum, with positive or negative output grounded.

INTERNAL IMPEDANCE—Less than 0.01 ohm at low audio frequencies; 0.1 ohm to 10 KC; 1 ohm to 40 KC.

TRANSIENT RESPONSE—For step change from no load to full, or full to no load, output recovers to within dc regulation limits of initial value within 1 millisecond.

OVERVOLTAGE CAPABILITY—See paragraph 2-12.

REMOTE PROGRAMMING RESISTANCE—1,000 ohms per volt of output.

REMOTE SENSING—See paragraph 2-9.

AMBIENT TEMPERATURE RANGE — —20°C to +45°C.

OUTPUT POLARITY—Swinging link for positive or negative ground or floating output.

CIRCUIT PROTECTION—Input ac line fused, dc output fused.

TERMINATIONS—Front: 5-way insulated binding posts. Rear: barrier-type terminal strips. Line cord is 3-conductor type.

CONTROLS—Main control and 10-volt vernier are of wirewound type. Panel calibration is approximate.

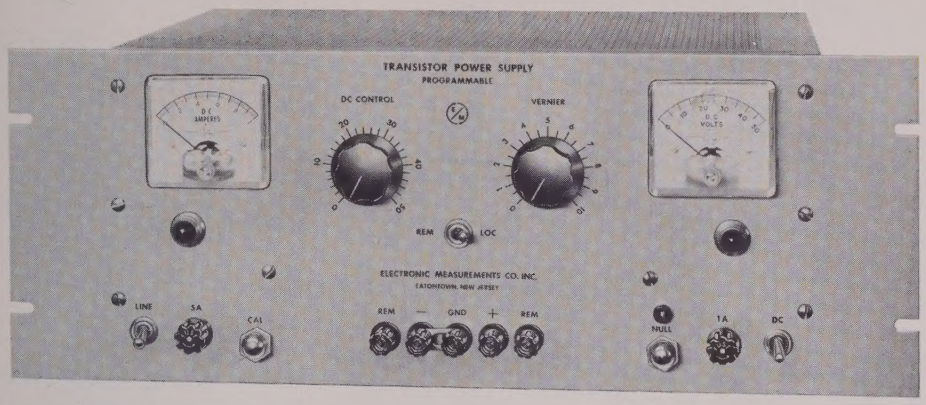
MOUNTING—Unit fits 19" standard racks and is equipped with rubber feet for table mounting. Top and bottom are protected by perforated metal covers.

FINISH—Smooth gray semi-gloss enamel Class 2 per MIL-E-15090.

INPUT POWER REQUIRED
Model 213A—324 watts, 365 VA.
Model 214A—377 watts, 427 VA.

DIMENSIONS—7 inches high, 11½ inches deep, 19 inches wide.

WEIGHT—35 pounds, approx.



PART 1 OF THIS MANUAL DESCRIBES THIS POWER SUPPLY.

PART 2 GIVES COMPLETE OPERATING INSTRUCTIONS.

PART 3 DESCRIBES THE CIRCUITRY.

PART 4 COVERS MAINTENANCE.

PART 5 CONTAINS THE PARTS LIST AND SCHEMATIC DIAGRAM.

PART 1
DESCRIPTION

1-1. INTRODUCTION. This Regatron Programmable Power Supply is a wide-range source of voltage-regulated d-c power. It is designed for use with transistors and for other applications requiring stable low voltages. Output is continuously adjustable from 0 to 100 volts on Model 214A, and from 0 to 50 volts on Model 213A. A vernier permits precise selection of output down to a fraction of a volt. Maximum rated current is 1 ampere. Further detailed performance data is presented in the Specifications Table on the opposite page.

1-2. PROGRAMMING. The output voltage of this power supply can be controlled remotely, or programmed, with a low power resistor connected to the REM and + output terminals. Output voltage then depends directly on the value of the programming resistor in the ratio of 1 volt per 1,000 ohms. This relationship remains constant over the entire output voltage range, even at a fraction of a volt. In programmed operation, regulation and stability are maintained within specified ratings. See paragraph 2-8 for instructions on programmed operation.

1-3. OVERVOLTAGE. Voltage output greater than the specified maximum is available at reduced output current. See paragraph 2-12 for instructions on overvoltage operation.

1-4. CONSTANT-CURRENT OUTPUT. This unit can be converted from constant-voltage to constant-current output by means of a simple external connection. See paragraph 2-16.

1-5. CHOPPER STABILIZATION. For units originally supplied without chopper stabilization, a conversion kit is available to incorporate this feature, or the unit may be returned to the factory for conversion.

1-6. STANDARD VERSIONS. This power supply is available in the following standard optional versions:

213A	or 214A	—without panel meters
213AM	or 214AM	—with panel voltmeter and milliameter
213AK	or 214AK	—without meters, with chopper stabilization
213AMK	or 214AMK	—with meters, with chopper stabilization

This instruction manual is applicable to all the above standard versions.

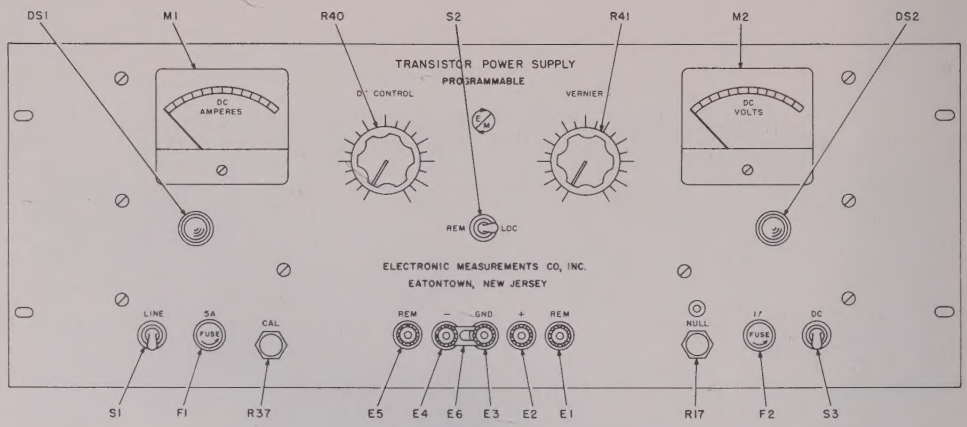


Figure 2-1. Front Panel.

PART 2
OPERATION

2-1. INSTALLATION. This unit operates on 105 to 125 volts, 50 to 60 cycles, single-phase ac. Input power required is stated in the Specifications Table.

The equipment may be table or rack mounted in a standard 19-inch rack. The rubber mounting feet may be removed from the bottom cover if they interfere with other rack-mounted equipment. Sufficient clearance should be allowed above and below the unit to provide adequate ventilation. The top dust-cover may be removed, if desired, to increase the ventilation.

2-2. CONTROLS AND TERMINATIONS.

See figure 2-1.

a. LINE switch: controls a-c line input.

b. DC switch: controls regulated d-c output.

c. REM-LOC switch: permits local or remote (programmed) control.

d. DC CONTROL: for adjustment of output voltage, calibrated to dial markings on panel.

e. VERNIER: for continuous fine adjustment through 10 volts. VERNIER and DC CONTROL settings are additive.

f. +, GND, and — terminals: for connection of load. A swinging link permits connection of either the positive or negative side of high voltage to chassis ground.

g. REM terminals: with + and — terminals, for connection of programming resistor.

h. TB1 (on rear of chassis): for connection of external voltage reference.

i. NULL ADJUSTMENT: for zeroing of balanced input detector. See paragraph 4-2.

j. CAL adjustment: for adjustment of output to panel markings or for exact 1,000 ohms per volt programmed operation. See paragraph 4-4.

2-3. FUSES. This unit contains the following fuses mounted on the front panel:

F1—5 amps (at left), in a-c line input circuit

F2—1 amp (at right), in + d-c circuit, to protect against short circuit or excess load across output.

2-4. PRELIMINARY. Before connecting to ac power, check that:

a. LINE switch is off (down).

b. DC switch is off (down).

c. DC CONTROL and VERNIER are at minimum, fully counterclockwise.

d. REM-LOC switch is at appropriate position: at LOC for panel control, at REM for remotely programmed operation.

e. Swinging link is at desired grounding position, or removed for floating output.

2-5. LINE AND LOAD CONNECTIONS

a. Connect line cord to ac power outlet.

b. Connect load to + and — output posts. It should be noted that the regulation of this unit is measured at the output posts. To maintain the specified regulation in actual service, the load wires must be heavy enough to prevent substantial voltage drops between the output posts and the load.

2-6. LOCAL OPERATION

a. Throw LINE switch on: green indicator should light.

b. Set DC CONTROL to desired voltage indicated on panel or voltmeter. If greater resolution is desired, this can be a coarse setting. The VERNIER, which is additive, provides the fine setting.

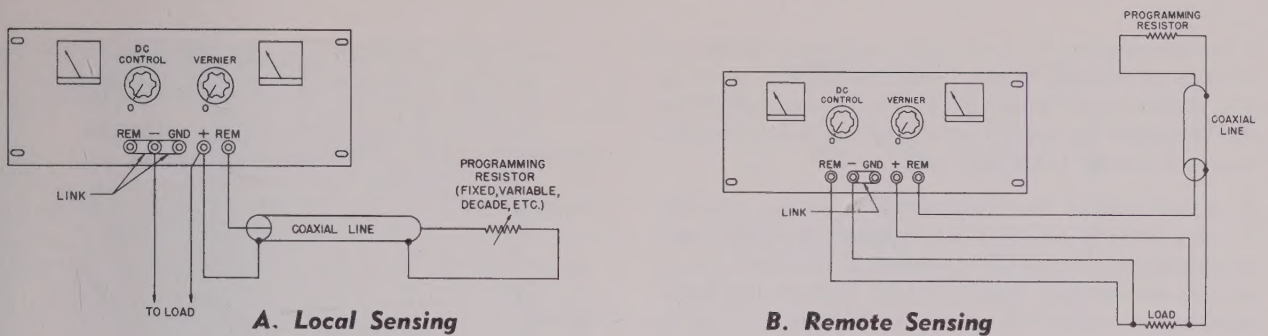


Figure 2-2. Programmed Operation

c. Turn VERNIER to precise voltage desired. For an output of 10 volts or less, set DC CONTROL to zero and select output with VERNIER alone to realize greater stability.
d. After one minute, throw DC switch on: red indicator should light. Desired voltage is now applied to load.

NOTE

Always allow a one-minute warmup period from a cold start before throwing DC switch on. This switch, when off, shorts the + and — output posts, thus effectively preventing application of any excess voltages to load during warmup. Subsequently, the DC switch can be thrown on or off with no danger of exceeding the desired output voltage.

2-7. USE OF REAR TERMINATIONS. On units equipped with rear-mounted terminations *only,* the preceding operation instructions apply without change. On units equipped with both front *and* rear terminations, the following additional procedure applies to local operation from the rear terminals:

a. Throw REM-LOC switch to REM.
b. On rear terminal board, connect REM posts to adjacent output posts.

In remotely programmed use, either set of terminations can be employed in the normal manner as described in paragraphs 2-8 and 2-9. Control will then be derived from the set of terminals in use.

2-8. PROGRAMMED OPERATION. As stated in paragraph 1-2, the output of this power supply can be controlled from a remote point, or programmed, with a resistor. For programmed operation, proceed as follows:

a. Throw DC and LINE switches off.
b. Throw REM-LOC switch to REM.
c. Connect the load and programming resistor as shown in figure 2-2A. Output voltage depends on programming resistance in the ratio 1:1,000. For example, to obtain 50 volts, use a 50,000 ohms resistor.
d. Throw LINE switch on.
e. Set DC CONTROL and VERNIER to zero.
f. Throw DC switch on. Programmed voltage is now applied to load.

Unless the programming resistor itself is physically shunted across the REM and + terminal posts, it is desirable to use shielded or coaxial cable, as shown in figure 2-2A, to prevent injection of ripple and noise from external sources. An insulated cable such as RG 58/U is recommended because of the fact that the coaxial sheath carries output potential.

For long-term or permanent programmed operation it is advisable to short out the internal controls. This will eliminate possible disturbance of programmed voltage by accidental rotation or vibration of the DC CONTROL or VERNIER, and will yield, in general, greater stability.

Programmed operation can be combined with use of the internal controls, when convenient or necessary, merely by omitting step e. of paragraph 2-8, and adjusting controls to any desired value. In this case the value of the programming resistor will be added to the values to which the internal controls are adjusted, and the total resistance will determine output voltage.

2-9. REMOTE SENSING, PROGRAMMED. Where load and control resistor are far from the unit but near each other the method of figure 2-2B will eliminate the effect of voltage drops in the output leads, yielding remote sensing for regulation at the load.

2-10. REMOTE SENSING, LOCAL. For remote sensing in local operation throw the REM-LOC switch to REM, connect a lead from the + REM post out to the + termination on the load, and from the — REM post out to the — termination on the load, and proceed as in paragraph 2-6.

2-11. PROGRAMMING SUGGESTIONS. Although the above programming instructions are illustrated with a single, fixed resistor as the remote control, it is evident that variable resistors, driven potentiometers, or fixed resistors wired to stepping switches can be employed to deliver voltages in a wide variety of time/amplitude patterns.

The time required for switching from one programmed voltage to another varies from the seconds range to the milliseconds range, depending upon conditions. Modifications for special switching times are available on special order from the factory.

It is also evident that programming can be manually or automatically actuated. As an example of automatic programming, figure 2-3 illustrates a four-level rotary stepper switch, each level of which controls one Regatron supply. As shown, the entire battery can be stepped through a sequence of four programmed outputs upon command.

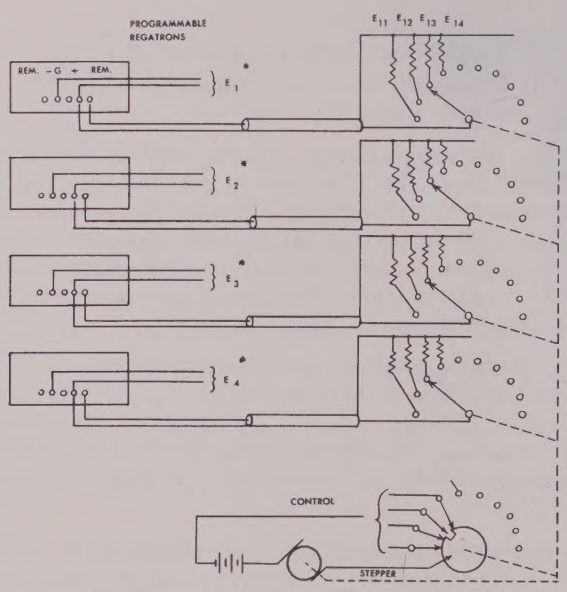


Figure 2-3. Programming with Stepper Switch. Each level controls one Regatron power supply.

In an extensive system, a central board may contain the switches or rheostats for the programming of several Regatron power supplies in different locations. In such a system it is practical to calibrate the control elements directly to dial markings, remembering that the accuracy of calibration depends upon the accuracy of the resistances and/or the dial markings.

2-12. OVERVOLTAGE OPERATION. This power supply is capable of voltage output higher than the specified maximum, at reduced output current. For overvoltage, an external programming resistor must be employed to substitute for or add to the resistance of the DC CONTROL and VERNIER in order to extend the control resistance range and, therefore, the output range. Figure 2-4 gives the applicable current deratings for overvoltage operation. For example, at 150 volts, Model 214A will deliver up to 380 ma. This voltage output could be obtained by setting the DC CONTROL and VERNIER to zero, and connecting a 150,000 ohm programming resistor as described in

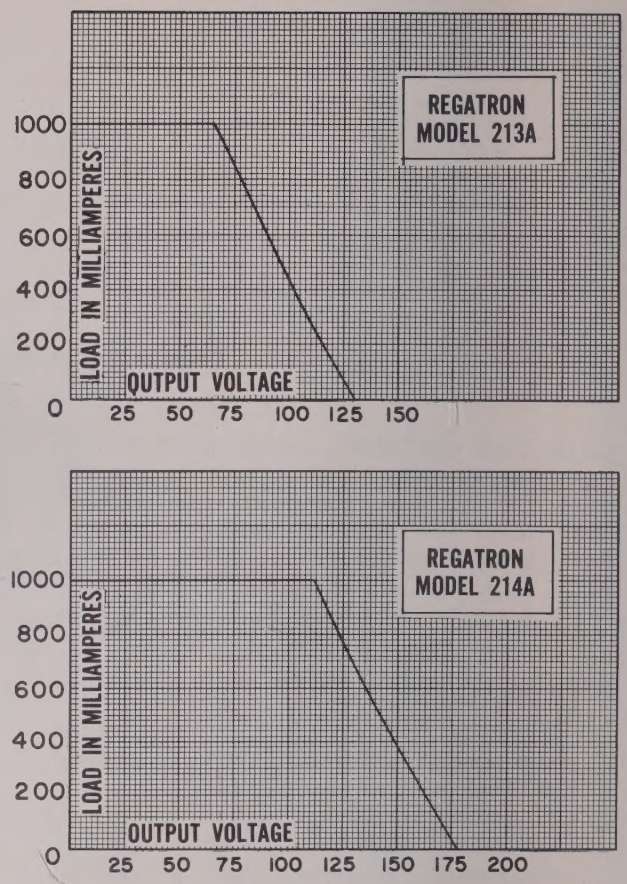


Figure 2-4. Overvoltage operation, showing current deratings.

paragraphs 2-8 and 2-9, and shown in figure 2-2A or 2-2B. Alternatively, the controls could be set for 100 volts, with an external 50,000 ohm programming resistor.

2-13. REFERENCE AGING. The voltage reference tube employed in this power supply exhibits progressive change of voltage with aging, typically, 0.5% for 1,000 hours of use. The resulting error at the output remains at a constant percentage throughout the voltage range of the power supply, but the absolute error varies directly with the output setting. Periodic calibration by the method described in paragraph 4-4 may be performed to eliminate any error due to aging of the reference tube.

2-14. EXTERNAL REFERENCE CONNECTION. If higher accuracy is required than is provided by the internal reference, a stable external reference source (of at least 85 volts) can be employed. The external reference source is connected via the rear-mounted terminal board TB1 as follows:

a. Remove the link across terminals 1 and 2 of TB1.

b. Connect the external reference across terminals 2 and 3 with the positive at terminal 3.

An external reference of between 85 and 87 volts may be directly connected as described. Above 87, each additional volt requires the insertion of 1,000 ohms of resistance between the external reference and terminal 3 on TB1 of the power supply. Thus an external reference of —150 volts requires a resistor of 63,000 ohms ± 1%. The resistor should be a wire-wound type using high stability alloy, since it directly affects the stability of the output voltage from the power supply.

2-15. USE AS VOLTAGE STANDARD. If a precision decade box is available for use as a remote programming control this power supply will serve as a voltage standard the accuracy of which (neglecting aging of the reference) will be slightly poorer than that of the decade box, even for a decade accuracy of 0.1%.

With the decade box connected as the remote programming resistor, output voltage will be indicated directly by the decade dials. Thus, the thousand-ohm-per-step dial indicates volts, the 10,000-per-step dial indicates tens of volts, and the 100,000-per-step dial indicates hundreds of volts.

In voltage-standard use the power supply should be calibrated as described in paragraphs 4-5 and 4-6; error due to aging of the internal reference can be nullified by periodic recalibration. If an external reference is to be employed, the calibration should be performed after connection of the external source (paragraph 2-14). It is also evident that, for minimal drift, the chopper-stabilized version of this power supply should be employed.

2-16. CONVERSION TO CONSTANT-CURRENT. For conversion from constant-voltage to constant-current output, proceed as follows:

a. Select a sample resistor, R_S in Figure 2-5 below, which will carry the load current and develop a sample voltage for the control system. To determine its value, select a sample voltage. Five to 10 volts is a good range. Although the voltage may be made as high as desired it must be remembered that the sample voltage subtracts from the available output voltage. If E_S is the sample voltage and I_L is the desired load current, then $R_S = E_S / I_L$, where R_S is in ohms and I_L is in amperes. The actual wattage will be $E_S \times I_L$. The resistor used should have a somewhat higher wattage rating.

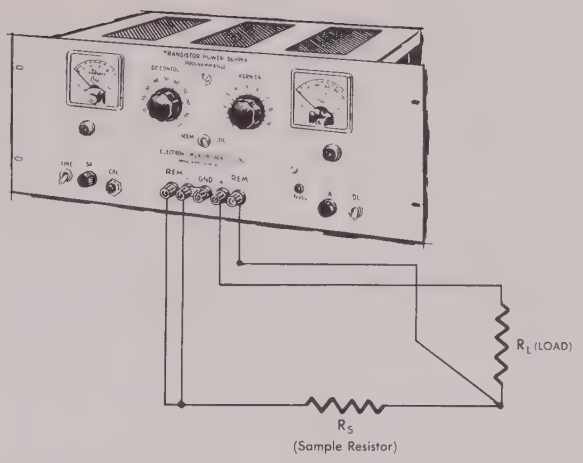


Figure 2-5. Conversion to constant-current operation

b. Make connections as shown in Figure 2-5 and set both panel controls to zero.

c. Throw REM-LOC switch to REM.

d. Throw the LINE switch on.

e. Bring current up to the desired value by turning the VERNIER up to the voltage selected as the sample in step a. above. In constant-current operation the VERNIER is the output control (for sample voltages up to 10 volts).

The conversion described above provides good dc regulation. The ac impedance of the power supply, however, is relatively low, and this should be noted in considering applications.

2-17. CHOPPER STABILIZED OPERATION. As stated in the specifications table, this unit achieves regulation of 0.01% or 3 mv, and stability of 0.05% + 2 mv for 8-hours when equipped with chopper stabilization. Although both ratings are conservative, note that the stability figure is specified with the unit in programmed operation, using an external resistor of high electrical and (in the case of a variable resistor) high mechanical stability. This rating can be realized only in such operation, and with the internal controls shorted out or set to zero to prevent them from contributing variations resulting from accidental rotation or vibration.

PART 3
CIRCUITRY

Note: Circuit references are made to the schematic diagram, except where indicated.

3-1. GENERAL. This power supply employs a full-wave rectifier, the positive output of which is applied to series amplifiers controlled by the regulator loop. The resulting regulated dc voltage constitutes the output.

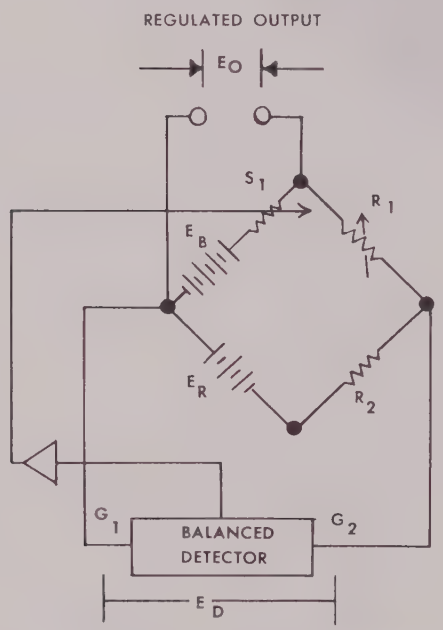


Figure 3-1. Output control configuration.

3-2. CONTROL SYSTEM, LOCAL AND PROGRAMMED. Figure 3-1 illustrates the output control configuration in simplified form. If inputs G_1 and G_2 are equal ($E_D = 0$) then:

$$\frac{E_0}{E_R} = \frac{R_1}{R_2} \text{ and } E_0 = E_R \times \frac{R_1}{R_2}$$

where E_0 = regulated output voltage
E_R = internal reference voltage
and R_2 is a fixed resistor.

Since E_R and R_2 are constant, $E_0 = KR_1$; or, the output voltage is dependent only upon the value of R_1 which, in local operation of the power supply, consists of the DC CONTROL and VERNIER. In programmed operation, R_1 is the remote programming resistor. In either local or programmed operation, the voltage output = $0.001R_1$, or, 1,000 ohms control resistance per volt of output.

In practice, R_2 can be adjusted with the CAL control (on the panel) for exact 1,000 ohms-per-volt programmed operation, or to calibrate output with panel dial markings.

3-3. REGULATOR SYSTEM, GENERAL. The regulator system employs a balanced input detector, V7, connected from the zero point of the input bleeder to the negative reference point (minus) to detect departures from balance. The amplifier error is applied to a high gain amplifier, V6, which drives the grids of the series amplifiers V8 through V13 in such a manner as to overcome the error. Because of the high gain of the system the error at equilibrium is very small. A gas tube, V5, maintains a very stable reference potential, and v/r tubes V1, V2, V3, and V4 maintain steady potentials for the tubes of the regulator system.

3-4. UNREGULATED DC SUPPLY. The main dc supply employs four Type F6 silicon diodes in a full-wave rectifier bridge, with filtering provided by a 320 UF electrolytic capacitor, C1. An 82K bleeder resistor, R2, which draws approximately 2 ma, discharges C1 upon turn-off of the power supply. Four rectifiers in a full-wave bridge comprise the 270 volt screen supply for series amplifiers V8 through V13, with filtering by an 80 UF electrolytic capacitor C2. This screen supply, the negative of which is returned directly to the cathodes of the series amplifiers, also serves as plate supply for the 6AU6 driver amplifier, V6.

Selenium rectifiers CR5, CR6, and CR7 deliver supply voltage to v/r tube V1, with capacitor C3, 40 UF, as filter. Rectifiers CR8, CR9, and CR10 deliver supply voltage to v/r tube V3, with capacitor C4 as filter.

3-5. REFERENCE. The internal reference potential for the power supply, also employed as a regulated service potential for the cathode of V6, is obtained across a gas-filled 85A2 tube, V5, which maintains a very stable drop of approximately—85 volts.CAL control R37 permits calibration of the control system to a precise output voltage based upon the exact potential across V5, and permits periodic recalibration to eliminate error resulting from aging of V5. When an external reference is employed (see paragraph 2-14) tube V5 is removed from the control system by the removal of the link across terminals 1 and 2 on TB1, but continues to supply —85 volts to V6.

The —150 volts from v/r tube V1, a type OA2, is dropped by R5 to 108 volts and further regulated by an OB2 tube V2 for use on the plates of the balanced input detector V7, and for the tube in the chopper stabilizer unit on models so equipped.

The —150 volts from V3 is similarly dropped to —108 volts by R9, further regulated by V4, and utilized for

the cathodes of V7 and the negative end of the voltage divider network composed of V14, V15 and R14 and R15. A 1 megohm resistor, R6, applies a momentary, high firing potential to v/r tube V4; this drops to 108 volts when the tube begins to conduct. A type 1N34 diode, CR16, functions as a one-way switch. CR16 disconnects V4 from the junction of R9 and R10 to permit momentary application of the high firing potential through R6. As soon as V4 has fired CR16 closes the path from the junction of R9 and R10, permitting normal flow through V4 and removing the momentary firing potential.

3-6. SERIES AMPLIFIERS. Paralleled Type 6550 beam power pentodes V8 through V13 are employed as series elements, or variable conductances. Control grids are direct-coupled to the plate of the driver amplifier V6. The cathodes of V8 through V13, from which positive, regulated output voltage is obtained, are removed from the + output terminal when DC switch S3 is thrown off. Throwing S3 off also shorts the + output terminal to minus to protect the power supply and the load from surges during standby operation.

3-7. BALANCED INPUT DETECTOR. A 12AX7 cathode-coupled amplifier V7 is employed as a balanced input detector, grid 7 of which is effectively at the positive of the reference potential, and grid 2 at the other null point on the opposite side of the control bridge. Regulated plate supply is taken from V2, and cathodes are returned through R16 to —108 volts regulated by V4. The NULL control R17 permits setting of the balanced input detector to zero difference between grids; capacitor C7 bypasses degenerative ac components appearing across R17.

Output from plate 6 of V7 is applied across a coupling and voltage divider network consisting of EM10 glow discharge regulator tubes V14 and V15 and resistors R15 and R14. The glow tubes couple plate potential to the grid of V6, maintaining a constant voltage drop which permits the grid to follow the potential at the plate of V7, thus constituting an effective dc coupling which avoids any substantial loss of gain.

Note that the chopper-stabilized version of this power supply employs a 12AY7 in place of the 12AX7 for tube V7.

Standard models include a ballast regulator tube, RT1, which maintains a stable 6.3 volts ac across the heater of V7. However, the ballast tube is not required in the chopper-stabilized version, and the RT1 socket is therefore employed for the chopper-stabilizer plug-in unit, with the slight wiring changes shown on the schematic diagram.

3-8. DRIVER AMPLIFIER. This stage employs a 6AU6 pentode, V6, in high gain, low current "starved" operation. Output is direct-coupled to the control grids of the series amplifiers, completing the regulator system loop.

3-9. CHOPPER-STABILIZATION. On units so equipped, the chopper-stabilizer is installed across the grids of the balanced input detector. Without chopper-stabilization this stage is subject to drift, with the result that output voltage may change up to .1% or 50 millivolts for 8-hours. The chopper unit, utilizing a contact modulator (chopper) continually samples the offset at grid 2 of V7, chops it to produce a square wave, amplifies, rectifies and filters it, and applies the resulting correction signal via reference grid 2 (removed from minus in chopper-stabilized version) to the regulator system to reduce the net offset to a vanishingly small value. The chopper-stabilizer adds a gain of approximately 1,000 to the regulator, with the result that regulation, as well as stability, improves to the figure shown in the Specifications Table.

3-10. OUTPUT CIRCUITRY. Connected across the output terminals are a resistor, R42, and a large electrolytic capacitor, C9, the values of which are selected to adjust the characteristic of the feedback loop for stable operation. Also across the output is an F6 diode, CR15, which protects the external load by presenting a low impedance to any reverse voltage which may develop when the unit is shut off. A type NE2 neon glow lamp, DS3, serves as a clamp to protect the internal reference, V5, from voltage surges when the power supply is switched from a high to a low voltage in remote control (programmed) operation. DS3 fires momentarily but is otherwise normally inoperative.
It should be noted that throwing the REM-LOC switch to REM removes the positive side of the reference from the minus side of the high voltage. This connection must be reestablished via the programming connections shown in figure 2-2.

PART 4
MAINTENANCE

Attention is called to the Warranty under which this equipment is sold, to be found opposite the Table of Contents page at the front of this book.

4-1. PARTS REPLACEMENT. An electrical parts list accompanies the schematic diagram in Part 5 of this book, and, along with the parts location illustrations, will identify all parts to be replaced. In general, replacement parts are completely defined by the values and tolerances indicated on the parts list. The following components, however, require special attention:

a. V1, V2, V3 and V4—Replacement of any of these tubes will affect null balance, which should therefore be readjusted as per paragraph 4-2.

b. V4—Replacement of the 85A2 will change the internal reference voltage somewhat, and necessitate recalibration as per paragraph 4-4. If the replacement 85A2 does not yield approximately correct calibration, or proves unstable, a satisfactory tube will be furnished by the factory upon request.

c. DC CONTROL and VERNIER controls—If either of these wirewound potentiometers is defective, it is advisable to obtain an exact replacement. If none is available locally, an order should be addressed to the factory. Any temporary substitute potentiometer should provide an arc of 280° effective rotation for the panel dial markings to represent output correctly.

4-2. NULL ADJUSTMENT. The NULL control, located on the front panel, permits adjustment of the balanced input detector to null, or zero level. This adjustment, which holds over the entire operating range, is made as follows:

a. Remove the acorn nut covering the control.

b. With the DC CONTROL and VERNIER at zero, throw the LINE switch on. After a minute (from cold start) throw the DC switch on.

c. Connect a voltmeter across the output + and — posts. Use 3 volt dc scale or lower.

d. Adjust the NULL control for zero on the meter. A very sensitive indication can be obtained by alternately connecting and disconnecting the meter lead.

4-3. NULL ADJUSTMENT FOR CHOPPER-STABILIZED UNITS.

a. With unit set for zero output connect a 100 millivolt meter across the output + and — terminals.

b. Rotate the NULL control to maximum in one direction and read the output in millivolts. Rotate NULL control to maximum in the opposite direction and read the output in millivolts. The difference between the two extremes should be less than 3 millivolts.

c. Rotate control to approximate center of range. When adjusted as described above the zero offset of the power supply should not exceed 1 millivolt. Usually, if this occurs, it is due to excessive grid current in the 12AY7. The tube should be changed and one used providing less than the specified offset.

4-4. CALIBRATION. The CAL control, also found on the front panel, requires adjustment for any one of three reasons:

For close agreement between panel markings and output, or for exact 1,000 ohms-per-volt ratio in programmed output, or for recalibration to either of the above after replacement of V5.

This adjustment can be performed in either of two ways: with an accurate voltmeter or with an external, precise source of voltage.

4-5. If an accurate voltmeter is employed, proceed as follows, referring to figure 4-1A.

a. Remove acorn nut covering CAL control. Connect meter across + and — terminals.

b. To calibrate panel markings, turn VERNIER to zero. On Model 213A set DC CONTROL to 50; on Model 214A set DC CONTROL to 100. Throw LINE, then DC switches on and adjust CAL control for 50 volt reading for Model 213A, for 100 volt reading for Model 214A, on the external voltmeter.

c. To calibrate for exact 1000 ohms-per-volt programmed output, turn VERNIER and DC CONTROL to zero. Set up Model 213A for programmed operation with a 50K resistor, and adjust CAL control for 50 volts on the external voltmeter. For Model 214A use a 100K resistor and adjust for 100 volts.

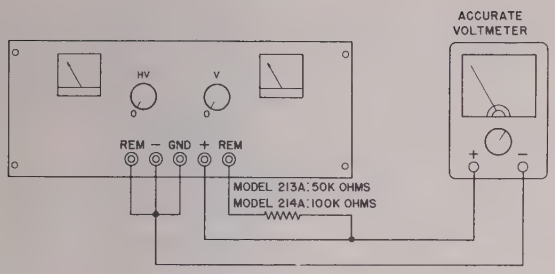


Figure 4-1A. Calibration—With Accurate Voltmeter for exact 1000 ohms-per-volt programming.

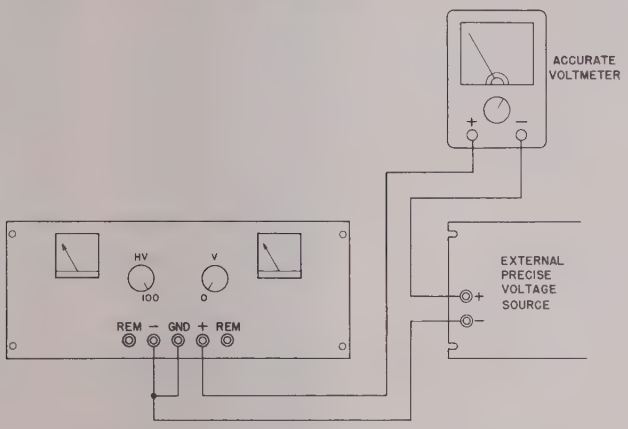


Figure 4-1B. Calibration With External, Precise Voltage Source.

4-6. If an external, precise source of voltage is employed, proceed as follows, referring to figure 4-1B.

a. Connect the negative outputs of the unit and the external voltage source together.

b. Connect an accurate voltmeter between the positive terminals of the Regatron unit and the external source.

c. Set the external source to exactly 50 volts for Model 213A, or 100 volts for Model 214A.

d. To calibrate panel markings, perform step c and turn VERNIER to zero. On Model 213A set DC CONTROL to 50; on Model 214A, to 100. Throw LINE, then DC switches on, and adjust CAL control for a zero reading on the external voltmeter. Use the lowest dc meter range available.

e. To calibrate for exact 1000 ohms-per-volt programmed output, perform step c. and turn VERNIER and DC CONTROL to zero. Program Model 213A with a 50K resistor, Model 214A with a 100K resistor. Throw LINE, then DC switches on, and adjust CAL control for zero on the external meter.

4-7. SERIES TUBE FAULTS. In selecting replacement series tubes, or when a malfunction appears to result from a faulty series tube, the following procedure is recommended:

a. Remove all series tubes but one.

b. Turn on unit, apply 1/N of full load current at a low voltage, where N= number of series tubes.

c. Check ripple and regulation.

d. Remove this series tube, place another series tube in another socket, and repeat steps b. and c. Repeat steps b. and c. for every other socket and tube, taking one at a time.

e. If one or more series circuits tests faulty, repeat the test in each case with a tube known to be satisfactory. If the repeated test proves favorable it may be assumed that the previous tube is defective. Otherwise the associated circuit should be checked for faults.

4-8. CLEANING AND LUBRICATION. This power supply employs forced air cooling. After extended service, therefore, considerable dust will be deposited on most surfaces within the unit. About twice a year the cover should be removed and all parts, and particularly the fan blades, should be cleansed free of dust and grime. Lubricate the fan motor once or twice a year by squeezing a few drops of light machine oil into the lubrication holes of the bearing straps.

4-10. TABLE OF RESISTANCES. The following table applies to Models 213A and 214A in both standard and chopper-stabilized versions. Values in the table are nominal and may vary as much as 20% among production units without causing difficulties. Conditions of measurement:

a. A-c line cord not connected to power.
b. No load connected.
c. LINE and DC switches off. Chassis ground floating, (swinging link disconnected from + or — post). LOC-REM switch at LOC.
d. DC CONTROL at 0. VERNIER at 0.
e. Readings from indicated tube pins to minus output post.

RESISTANCES

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	2 meg	0	—	0	2 meg	—	0		
V2	1 meg	0	—	0	1 meg	—	0		
V3	0	100K	—	100K	0	—	100K		
V4	0	100K	—	100K	0	100K*	100K		
V5	0	100K	0	100K	0	∞ *	100K		
V6	500K	120K	0	0	5 meg	200K	120K		
V7	3 meg	80K	250K	0	0	3 meg	0	250K	3
V8 thru V13	—	∞	50K	1.5 meg	5 meg	—	∞	∞	
V14	3 meg	∞							
V15	500K	∞							

*Tie point only.

4-11. TABLE OF VOLTAGES. The values in the Table of Voltages below are nominal and may vary as much as 20% among production units without causing difficulties. The measurements were made with a 100,000 ohms-per-volt meter, under the following conditions:

a. LINE input 115 volts ac. LINE and DC switches on.
b. DC CONTROL at 90, VERNIER at 10.
c. No load connected.
d. Chassis ground floating, (swinging link disconnected from + or — post). LOC-REM switch at LOC.
e. Readings from indicated tube pins to minus post.

VOLTAGES

All voltages are dc unless noted.

TUBE	MODEL	PIN								
		1	2	3	4	5	6	7	8	9
V1	213A 214A	150	0	—	0	150	—	0		
V2	213A 214A	108	0	—	0	108	—	0		
V3	213A 214A	0	—150	—	—150	0	—	—150		
V4	213A 214A	0	—108	—	—108	0	—	—108		
V5	213A 214A	0	—85	—	—85	0	—	—85		
V6	213A	—85	—85	6.3 AC	6.3 AC	5	—40	—85		
V6	214A	—85	—85	6.3 AC	6.3 AC	55	—40	—85		
V7	213A 214A	108	0	0.8	6.3 AC	6.3 AC	35	0	0.3	6.3 AC
V8 thru V13	213A	—	6.3 AC	150	310	5	—	6.3 AC	50	
V8 thru V13	214A	—	6.3 AC	200	360	55	—	6.3 AC	100	

Total voltage across V14 and V15: 115

4-9. TROUBLE-SHOOTING TABLE. Referenced below are several possible symptoms of troubles which can develop, with their most likely causes, and remedies. This table is intended to serve as a brief guide in trouble shooting.

SYMPTOM	CAUSE	REMEDY
1. Unit is dead when LINE switch is thrown on.	a. Fuse F1 blown.	a. Replace with 5 amp fuse.
	b. Fuse F1 open, defective.	b. Check F1 for continuity and replace if necessary.
2. Fuse F1 blows repeatedly.	a. F6 rectifier (CR1, 2, 3, or 4) shorted.	a. Replace CR1, 2, 3, or 4.
	b. 8J1 rectifier (CR5 through CR10) shorted.	b. Replace 8J1.
	c. F6 rectifier (CR11 thru CR14) shorted.	c. Replace F6.
3. DC fuse F2 blows, output to zero.	a. Short circuit load.	a. Check load.
	b. Overload, above 1 AMP.	b. Check load.
	c. Fuse F2 open, defective.	c. Check F2 for continuity and replace if necessary.
	d. With load connected, DC CONTROL or VERNIER potentiometer is open.	d. Check R40, R41 for resistance. See paragraph 4-1.
	e. With load connected, external control line open.	e. Check external control line.
	f. F6 diode CR15 shorted (across output terminals).	f. Replace.
4. No control of output, voltmeter pins at top of scale.	a. 6550 series amplifier (V8 through V13) shorted.	a. Replace. See paragraph 4-1. Also check screen and cathode resistors of affected series stage.
	b. 6AU6 amplifier V6 inoperative.	b. Replace.
	c. HV CONTROL or VERNIER potentiometer open.	c. Check R40, R41 for resistance. See paragraph 4-1.
	d. In remote (REM) programmed operation, external control resistor open.	d. Check external control resistor.
5. No control of output, voltmeter at zero, fuse F2 not blown.	a. 6550 series amplifier (V8 through V13) defective.	a. Replace. See paragraph 4-1.
	b. 12AX7 balanced input detector V7 defective.	b. Replace.
	c. Ballast tube RT1 defective.	c. Replace.
6. Voltmeter indication disagrees with control settings at full scale.		a. Recalibration necessary.
7. Output voltage lower than control setting but recalibration impossible or out of CAL range.	a. 85A2 reference tube V5 shifted voltage.	a. Replace. See paragraph 4-1. Also recalibrate.
	b. OA2, V3, defective.	b. Replace.
8. Output voltage lower than control setting in chopper stabilized unit.	a. Tube V1 (12AX7) in chopper-stabilizer unit defective.	a. Replace.

SYMPTOM	CAUSE	REMEDY
9. Poor line regulation.	a. Defective V1, V2, V3, V4, V5, or V7.	a. Replace. See paragraph 4-1.
	b. Defective F6 rectifier (CR1, 2, 3, or 4)	b. Replace.
10. Poor load regulation.	a. Poor load connections or high resistance in load leads.	a. Check load connections.
	b. 6550 series amplifier (V8 through V13) defective.	b. Replace. See paragraph 4-7.
	c. Chopper inoperative.	c. Replace chopper.
11. Excessive zero-offset (drift) in chopper-stabilized unit.	a. Tube V7 defective.	a. Replace.
	b. Chopper inoperative.	b. Replace chopper.
12. NULL adjustment impossible.	a. Fuse F2 blown.	a. Replace.
	b. Defective V1, V2, V3, V4, V5, V7, V14, or V15.	b. Replace.
13. High ripple.	a. External control resistor and control line are coupling stray ac signal to unit.	a. Shield control and/or line.
	b. Defective V3, V4, V5, V6, or V7.	b. Replace.
	c. Defective C1, C2, C3, C8, or C9.	c. Replace.
14. DC changes abruptly at a periodic rate.	a. Defective V1, V2, V3, V4, V5, or V14 or V15.	a. Replace. Recalibrate if V5 is replaced.

ELECTRICAL PARTS LIST

CHOPPER STABILIZER UNIT 336B34

REF SYMBOL	DESCRIPTION	PART OR TYPE NO.	MFR. SYMBOL
C1	Capacitor, mica, 27 UUF, 500VDC	CM19B270-J	MICAMOLD
C2	Capacitor, paper, .02 UF, 400VDC	354A-168	MICAMOLD
C3	Capacitor, paper, .02 UF, 400VDC	354A-168	MICAMOLD
C4	Capacitor, paper, .02 UF, 400VDC	354A-168	MICAMOLD
C5	Capacitor, electrolytic, non-polarized, tantalum 20 UF, 150VDC	TAE20-25SDLK-NP	*I.E.I.
K1	Chopper, SPDT	175	AIRPAX
R1	Resistor, fixed, comp., 120K ±10%, ½W	EB	AB
R2	Resistor, fixed, comp., 33K ±10%, ½W	EB	AB
R3,R6	Resistor, fixed, comp., 4.7 MEG ±10%, ½W	EB	AB
R4	Resistor, fixed, comp., 100K ±10%, ½W	EB	AB
R5,R7	Resistor, fixed, comp., 680K ±10%, ½W	EB	AB
R8	Resistor, fixed, comp., 56K ±10%, ½W	EB	AB
R9	Resistor, fixed, comp., 270K ±10%, ½W	EB	AB
R10	Resistor, fixed, comp., 1 MEG ±10%, ½W	EB	AB
V1	Tube, 12AX7	12AX7	RCA

* *International Electronic Industries, Inc.*

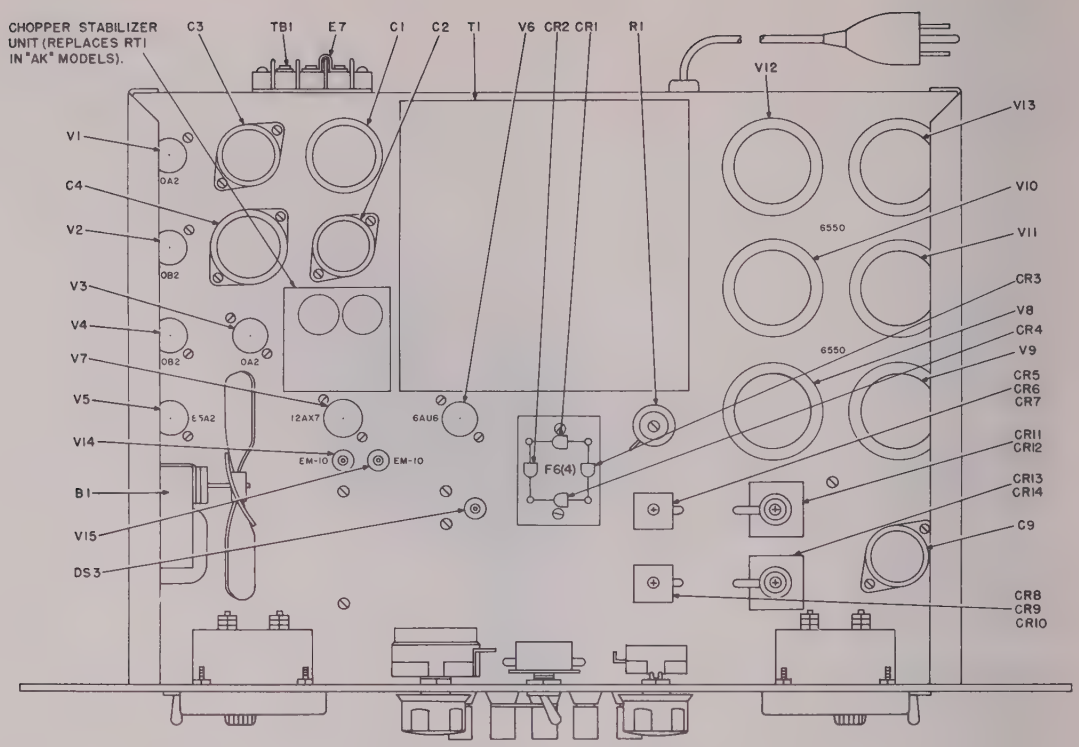


Figure 5-1. Parts Locations.

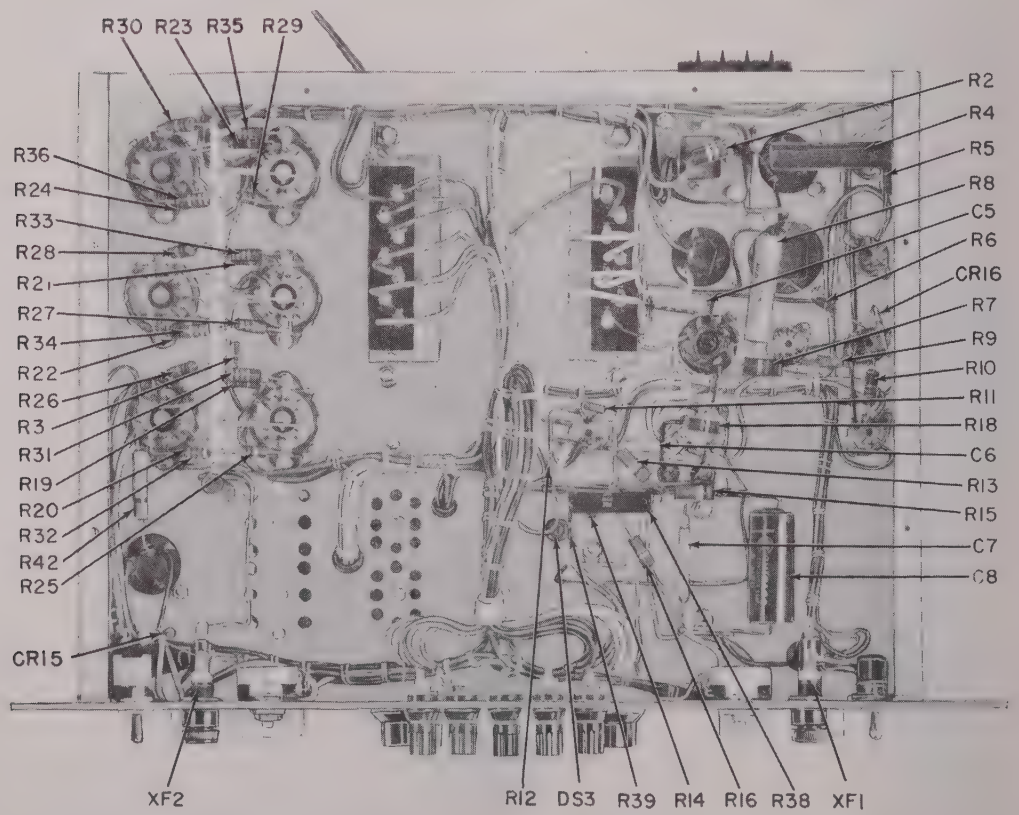


Figure 5-2. Parts Locations.

PARTS LIST

MODELS 213A/AK, 214A/AK
PROGRAMMING CONSTANT
1000 ohms -per-volt
115 volts, 50-60 cps input

Revised 4-63

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
B1	Motor, shaded pole, 115V, 50-60 cps, 4 in. fan blade	DYAB-570-3	Barber-Coleman
*C1	Capacitor, electrolytic, 320uf, 300 VDC, insul. sleeve	D31962	Sprague
*C2	Capacitor, electrolytic, 80uf, 300 VDC, insul. sleeve	D31964	Sprague
*C3,9	Capacitor, electrolytic, 40uf, 450 VDC, insul. sleeve	D19939	Sprague
C5	Capacitor, mica, 15uuf ±5%, 500 VDC	CM20B150J	Micamold
C6	Capacitor, mica, 220uuf ±5%, 500 VDC	CM20B221J	Micamold
*C7	Capacitor, electrolytic, 25uf, 25 VDC, insul. sleeve	Type 530	Neuberger
C8	Capacitor, mylar, 0.5uf +20% -10%, 400 VDC	Type 2110BM	Chicago Cond.
CORD	Line Cord, 7' lg., #18 gauge, 3 cond., 3 prong plug	346-B-52	EMC
*CR1-4,11-14,CR15	Rectifier, silicon	CER71	Solitron
*CR5-CR10	Rectifier, selenium	8J1	Radio Receptor
*CR16	Diode, silicon	HC69	Solitron
*DS1,2	Lamp, 6.3 V, 0.25A	44	G.E.
*DS3	Lamp, neon	NE-2	EMC
E1,2	Post, binding, red	29-3R	Grayhill
E3,4,5	Post, binding, black	29-3B	Grayhill
E6	Shorting link	938-L	General Radio
E7	Shorting link	141-J	Cinch-Jones
*F1	Fuse, cartridge, 5A	3AG5	Sightmaster
*F2	Fuse, cartridge, 1A	3AG1	Sightmaster
J1	Tip jack, nylon	105-603	E.F.Johnson
J3	Socket, octal	9977	Cinch-Jones
M1	Ammeter, 0-1 ADC ±2% full scale	Model 649/A1	EMC
M2	Voltmeter, 0-50 VDC ±2% full scale (213A/AK)	Model 649-V50	EMC
M2	Voltmeter, 0-100 VDC ±2% full scale (214A/AK)	Model 649/V100	EMC
R1	Resistor, fixed, WW, vitreous enamel, 3 ±5%, 25W	25F3	Ward Leonard
R2	Resistor, fixed, comp., 82K ±10%, 2W	HB-8231	Allen-Bradley
R3	Resistor, fixed, comp., 4.7 megohms ±10%, ½W	EB-4751	Allen-Bradley
R4	Resistor, fixed, WW, vitreous enamel, 10K ±5%, 20W	1841	Ohmite
R5	Resistor, fixed, comp., 5100 ±5%, 1W	GB-5125	Allen-Bradley
R6	Resistor, fixed, comp., 1 meghom ±10%, ½W	EB-1051	Allen-Bradley
R7	Resistor, fixed, comp., 1000 ±10%, 2W	HB-1021	Allen-Bradley
R8	Resistor, fixed, WW, ceramic, 4000 ±5%, 10W	10KT4K	Sprague
R9	Resistor, fixed, comp., 3600 ±5%, 1W	GB-3625	Allen-Bradley
R10	Resistor, fixed, comp., 5600 ±5%, 1W	GB-5625	Allen-Bradley
R11,14	Resistor, fixed, comp., 330K ±10%, ½W	EB-3341	Allen-Bradley
R13,15	Resistor, fixed, comp., 100K ±10%, ½W	EB-1041	Allen-Bradley
R16	Resistor, fixed, comp., 150K ±10%, 1W	GB-1541	Allen-Bradley
*R17	Resistor, variable, WW, 3000 ±5%, 2W, linear taper, 1/4 in. dia. by 1/8 in. lg. slotted shaft, Series 43	CM18923	Clarostat
R18	Resistor, fixed, comp., 220K ±10%, 1W	GB-2241	Allen-Bradley
R19-24	Resistor, fixed, comp., 82 ±10%, 1W	GB-8201	Allen-Bradley
R25-30	Resistor, fixed, comp., 10 ±10%, 1W	GB-1001	Allen-Bradley
R31-36	Resistor, fixed, comp., 470 ±10%, 1W	GB-4711	Allen-Bradley
*R37	Resistor, variable, WW, 10K ±5%, 2W, linear taper, 1/4 in. dia. by 1/8 in. lg. slotted shaft, Series 43	CM18924	Clarostat
*R38	Resistor, fixed, WW, 76K ±1%, 3W	Type P3-W	Prec. Resistor
*R39	Resistor, fixed, WW, 3000 ±1%, ½W	Type TX-178	Prec. Resistor
*R40	Resistor, variable, WW, 50K ±5%, 3W, linear taper, 1/4 in. dia. by 1/2 in. shaft, Series 58 (213A/AK)	CM20403	Clarostat
*R40	Resistor, variable, WW, 100K ±5%, 4W, linear taper, 1/4 in. dia. by 1/2 in. lg. shaft, Series 10 (214A/AK)	CM18927	Clarostat
*R41	Resistor, variable, WW, 10K ±5%, 2W, linear taper, 1/4 in. dia. by 1/2 in. lg. shaft, Series 43	CM21189	Clarostat

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
R42	Resistor, fixed, WW, 1 ±5%, 1W	Type BW1	Int'l Resistance
R43	Resistor, fixed, comp., 4.7 ±5%, 1W	GB-47G5	Allen-Bradley
*RT-1	Ballast tube (213A, 214A)	AMP 3-4	Amperite
*S1	Switch, toggle, SPST	160-73	Carling
*S2	Switch, toggle, DPST	2BK62-73	Carling
*S3	Switch, toggle, DPDT	2GL53-73	Carling
T1	Transformer, power and reference	5018	EMC
TB1	Barrier strip, 3 terminal	3-141-Y	Cinch-Jones
TB2	Barrier strip, 5 terminal (rear termination only)	5-141-Y	Cinch-Jones
*V1,3	Electron tube	0A2	RCA
*V2,4	Electron tube	0B2	RCA
*V5	Electron tube	85A2/0G3	Amperex
*V6	Electron tube	6AU6	RCA
*V7	Electron tube (213A - 214A)	12AX7	RCA
*V7	Electron tube (213AK - 214AK)	12AY7	G.E.
*V8-V13	Electron tube	6550 or KT88	Tung-Sol British Ind.
XF1,2	Extractor post, fuse, miniature	342003	Littelfuse
XDS1	Holder assembly, pilot lamp, green faceted lens	100	Drake
XDS2	Holder assembly, pilot lamp, red faceted lens	100	Drake

ELECTRICAL PARTS LIST
CHOPPER STABILIZER UNIT
336-A-32

C1	Capacitor, mica, 27uuf ±5%, 500 VDC	CM19B270J	Arco
C2,3,4	Capacitor, mylar, 0.022uf ±10%, 200 VDC	107C223K	Pyramid
*C5	Capacitor, tantalum, etched foil, non polarized, 20uf ±20%, 25 VDC	TAE20-25SDLK-NP	I.E.I.**
*K1	Chopper, SPDT, 6.3V, 60 CPS	Model 175	Airpax
P3	Plug, octal	86-CP8	Amphenol
R1	Resistor, fixed, comp., 120K ±10%, ½W	EB-1241	Allen-Bradley
R2	Resistor, fixed, comp., 33K ±10%, ½W	EB-3331	Allen-Bradley
R3,6	Resistor, fixed, comp., 4.7 megohms ±10%, ½W	EB-4751	Allen-Bradley
R4	Resistor, fixed, comp., 100K ±10%, ½W	EB-1041	Allen-Bradley
R5,7	Resistor, fixed, comp., 680K ±10%, ½W	EB-6841	Allen-Bradley
R8	Resistor, fixed, comp., 56K ±10%, ½W	EB-5631	Allen-Bradley
R9	Resistor, fixed, comp., 270K ±10%, ½W	EB-2741	Allen-Bradley
R10	Resistor, fixed, comp., 1 megohm ±10%, ½W	EB-1051	Allen-Bradley
*V1	Electron tube	12AX7	RCA

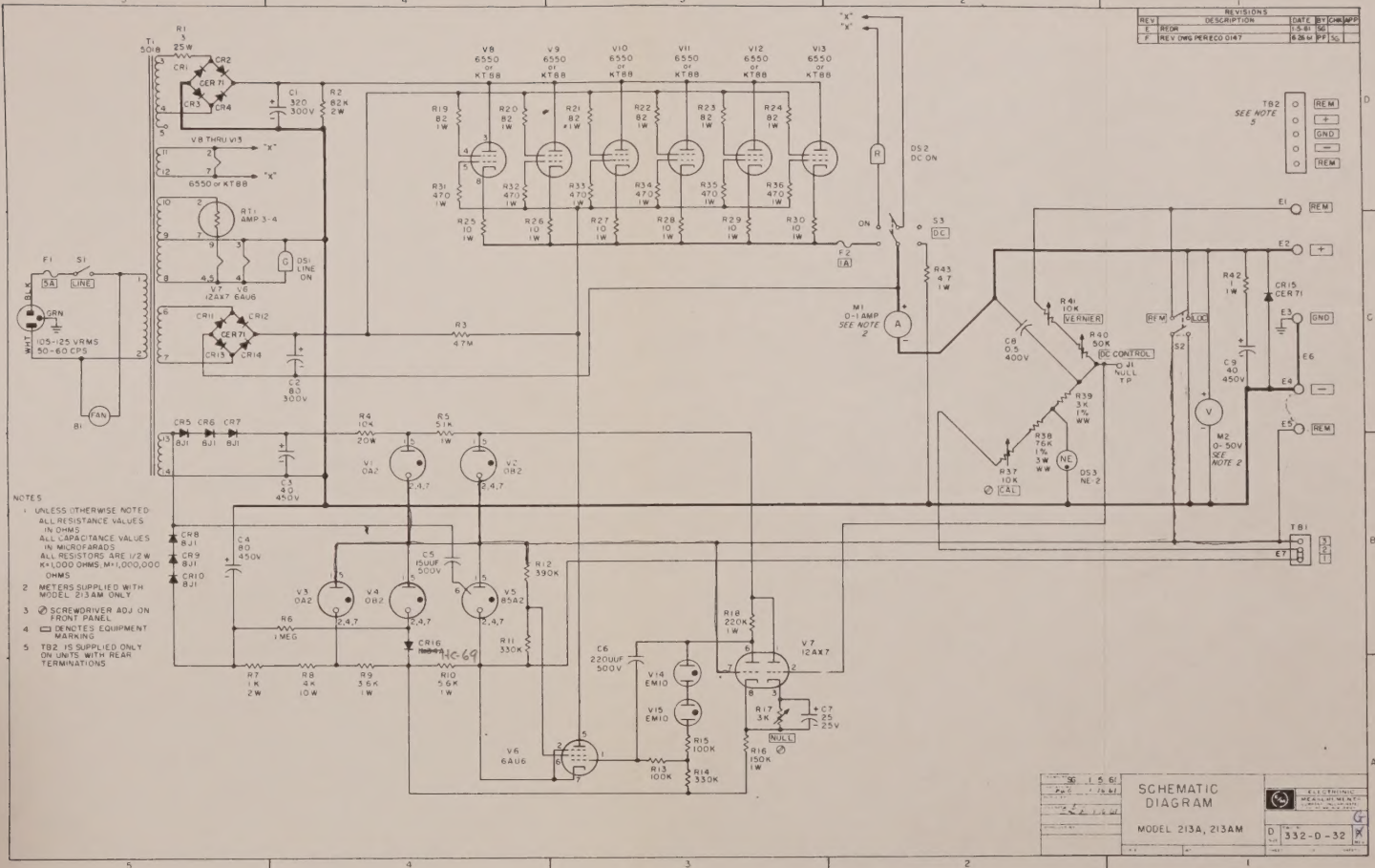
** International Electronics Industries, Inc.

PARTS LIST ADDENDUM
220 volts, 50-60 cps input

B1	Motor, shaded pole, constant speed, 220v., 50-60 cps, 4 in. fan blade	1075-3174	Howard
*F1	Fuse, cartridge, 3A.	3AG3	Sightmaster
*S1	Same as for 115 volt input		
T1	Transformer, power and reference		EMC

NOTES:

1. *ASTERISKED PARTS are recommended spares in quantity one per reference symbol, except fuses, which are three per reference symbol.
2. WHEN MAKING REPLACEMENTS: Part numbers are indicative of stock employed at the time of compilation of this list. Unless otherwise noted, and except for Electronic Measurements (E/M) numbers, "or equal" parts may be used for replacement. Electronic Measurements reserves the right to replace a part with an "or equal" part.
3. WHEN ORDERING PARTS FROM E/M: Include model and serial numbers of the instrument. Note carefully and include the letter suffix of any transformer number. In case of a discrepancy between a parts list number and the number actually printed on the part, employ the latter.
4. RECOMMENDED SPARES. When electrolytic capacitors are to be stored as spares for a year or more, request Technical Note 32.


REVISIONS
REV | DESCRIPTION | DATE | BY | CHK | APP
E | REDR | 1-5-61 | SG
F | REV DWG PER ECO 0147 | 6-26-61 | PF | SG
T1 5048
R1 5 25W
CR1 CR2 CR3 CR4 CER 71
C1 320 300V
R2 62K 2W
V8 THRU V13
6550 or KT88
V8 6550 or KT88
V9 6550 or KT88
V10 6550 or KT88
V11 6550 or KT88
V12 6550 or KT88
V13 6550 or KT88
R19 82 1W
R20 82 1W
R21 82 1W
R22 82 1W
R23 82 1W
R24 82 1W
R31 470 1W
R32 470 1W
R33 470 1W
R34 470 1W
R35 470 1W
R36 470 1W
R25 10 1W
R26 10 1W
R27 10 1W
R28 10 1W
R29 10 1W
R30 10 1W
RT1 AMP 3-4
V7 12AX7 V8 6AU6
G DS1 LINE ON
F1 5A
S1 LINE
BLK
GRN
WHT
105-125 VRMS 50-60 CPS
B1 FAN
CR11 CR12 CR13 CR14 CER71
C2 80 300V
R3 4.7M
CR5 CR6 CR7 8J1
C3 40 450V
R4 10K 20W
R5 51K 1W
V1 0A2
V2 0B2
2.4.7
CR8 CR9 CR10 8J1
C4 80 450V
V3 0A2
V4 0B2
V5 85A2
C5 150UF 500V
R12 390K
R6 1 MEG
CR16 SC-69
R7 1K 2W
R8 4K 10W
R9 3.6K 1W
R10 5.6K 1W
R11 330K
V6 6AU6
C6 220UUF 500V
V14 EM10
V15 EM10
R13 100K
R14 330K
R15 100K
R16 150K 1W
R17 3K
NULL
C7 25 25V
R18 220K 1W
V7 12AX7
"X" "X"
DS2 DC ON
S3 DC
FZ 1A
ON
R43 4.7 1W
M1 0-1 AMP SEE NOTE 2
R41 10K VERNIER
R40 50K DC CONTROL
J1 NULL TP
C8 0.5 400V
R39 3K 1% WW
R38 76K 1% 3W WW
R37 10K CAL
DS3 NE-2
S2 REM LOC
R42 1 1W
CR15 CER 71
C9 40 450V
M2 0-50V SEE NOTE 2
TB2 SEE NOTE 5
REM + GND - REM
E1 E2 E3 E6 E4 E5 E7
TB1
NOTES
1 UNLESS OTHERWISE NOTED ALL RESISTANCE VALUES IN OHMS ALL CAPACITANCE VALUES IN MICROFARADS ALL RESISTORS ARE 1/2 W K=1,000 OHMS, M=1,000,000 OHMS
2 METERS SUPPLIED WITH MODEL 213AM ONLY
3 SCREWDRIVER ADJ ON FRONT PANEL
4 DENOTES EQUIPMENT MARKING
5 TB2 IS SUPPLIED ONLY ON UNITS WITH REAR TERMINATIONS
SG 1.5.61
SCHEMATIC DIAGRAM
MODEL 213A, 213AM
ELECTRONIC MEASUREMENTS
D 332-D-32
G

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